Valuing Soil Conservation Benefits of Agroforestry Practices

By

Subhrendu Pattanayak and D. Evan Mercer

FPEI Working Paper No. 59

The Forestry Private Enterprise Initiative (FPEI) is a cooperative project of the Southeastern Center for Forest Economics Research (SCFER) with the Forestry Support Program (FSP), the United States Agency for International Development (AID), Bureau for Science and Technology (S&T) [through its Office of Forestry, Environment, (and Natural Resources (FENR)], Organization for International Cooperation and Development (OICD), the United States Department of Agriculture (USDA) Forest Service Southern Research Station (SRS), and North Carolina State University (NCSU).

Pattanayak, Subhrendu and D. Evan Mercer. 1996. Valuing soil conservation benefits of agroforestry practices. Southeastern Center for Forest Economics Research, Research Triangle Park, NC. FPEI Working Paper No. 59. 21 p.

About the Author(s)

Subhrendu is Ph.D. candidate at the Nicholas School of the Environment, Duke University, Durham, NC. D. Evan Mercer is research economist at USDA-Forest Service, Southern Research Station, Research Triangle Park, NC.

About FPEI Working Papers

FPEI working papers are a special series of SCFER working papers issued by the Southeastern Center for Forest Economics Research for the purpose of sharing the research findings of the Forestry Private Enterprise Initiative. These papers are distributed in order to promote the timely release of new theories, data, and findings. Working papers represent various levels of research findings and readers are encouraged to contact the author(s) for more information. Some of the papers may be published in modified form elsewhere. An updated list and copies of FPEI working papers are available from the Center at P.O. Box 12254, Research Triangle Park, NC 27709, 919/549-4093. Selected papers may also be downloaded from the World Wide Web site http://www.rtp.srs.fs.fed.us/econ/.

VALUING SOIL CONSERVATION BENEFITS OF AGROFORESTRY PRACTICES

Subhrendu Pattanayak and D. Evan Mercer

ABSTRACT

Although advocates of agroforestry have promoted soil conservation as one of its primary benefits, empirical estimates of these benefits have been lacking due to temporal and spatial complexity of agroforestry systems and soil resource dynamics. This study aims to reduce this gap by designing and testing a three stage farm level productivity methodology for economic evaluation of soil conservation benefits of agroforestry. Stage 1 quantifies the relationship between soil conservation, agroforestry, and soil quality. In Stage 2, the effects of changes in soil quality on individual household agricultural production are estimated. Finally, in Stage 3 these changes in production are valued at net market prices. The data to test this framework were drawn from two USAID/Government of Philippines projects that introduced contour hedgerow agroforestry in the Eastern Visayas, Philippines. Multiple regression analysis is used in each stage to establish the relationship between the agroforestry practice, soil quality and changes in farm-household income. The value of soil conservation is measured in terms of the change in net household income which is the true measure of change in the economic welfare of the household. The results indicate that agroforestry-related soil conservation does benefit the farmer, with the 'average' farmer gaining 114 pesos annually. This in itself provides insufficient incentive for the farmer to invest in agroforestry in this case because the direct opportunity costs of agroforestry adoption and maintenance result in a negative overall contribution to individual household income. However, the specific soil conservation benefit calculations do not account for several significant off-site and on-site benefits external to the individual households. In addition, all long run soil conservation benefits (and particularly improvements in the agro-ecological profile) may not have been realized in the short ten year period since the initiation of the agroforestry project. Thus, even though net benefits of agroforestry is negative, there may be good reason for society to encourage the farmers to practice agroforestry to conserve the soil and enhance overall societal welfare.

VALUING SOIL CONSERVATION BENEFITS OF AGROFORESTRY PRACTICES

Subhrendu Pattanayak and D. Evan Mercer

1. Effect of Agroforestry Practices on Soil Conservation

Agroforestry practices encompass an entire spectrum of land use systems in which woody perennials are deliberately combined with agricultural crops and/or animals in some spatial or temporal arrangement (Lundgren and Raintree, 1982). Advocates have contended that soil conservation is one of its primary benefits (Young, 1989). The presence of woody perennials in agroforestry systems may effect several bio-physical and bio-chemical processes that determine the health of the soil substrate (Nair, 1993). The less disputed of the effects of trees on soil include: amelioration of erosion, primarily through surface litter cover and under story vegetation; maintenance or increase of organic matter and diversity, through continuous degeneration of roots and decomposition of litter; nitrogen fixation; enhancement of physical properties such as soil structure, porosity, and moisture retention due to the extensive root system and the canopy cover; and enhanced efficiency of nutrient use because the-tree-root system can intercept, absorb and recycle nutrients in the soil that would otherwise be lost through leaching (Sanchez, 1987).

The objective of this study, a sub-component of a larger project[1], is to design and test a framework for valuing the soil conservation impacts of agroforestry. Our concept of value, in this study, reflects three perspectives: (I) anthropocentric, (ii) economic, and (iii) a narrow edaphic viewpoint. In a world of increasing environmental consumption and scarcity of resources, relative economic values and anthropocentricism are central. Economic analyses view soil conservation in terms of its value relative to other scarce goods and services. Our analysis examines one of the most crucial values of soil conservation, its role in maintaining and enhancing agricultural productivity. This narrow edaphic vision is justified on two grounds (Lutz et al, 1993). First, since the farmer is the primary soil conservation decision maker, only a tyrannical state or a massive subsidy program could induce soil conservation. in the absence of substantial economic benefits for the farmer. Second, land use problems are generally highly dependent on site-specific biophysical characteristics, which can vary significantly even within small areas (Pagiola, 1993). A farm-level approach is a more appropriate way to incorporate site-specific events than a society-level approach requiring aggregation of heterogenous variables. We do not contend that on-site benefits to farmers are the most important benefits of soil conservation (see Gregersen et al. 1987). Rather, given the central role of farmers in conserving soil, on-site benefits are more crucial. For example, it has been argued that while in the U.S. the off-site benefits clearly outweigh the on-site gains (Clark et al., 1985; Crosson and Stout, 1983), for developing countries the opposite holds true (Repetto and Cruz, 1991; Magrath and Arens, 1989). In any case, the market value of the preserved agricultural productivity provides a lower bound of the value of soil conservation. Estimation of this value should help policy makers determine the appropriate levels of support for agroforestry.

---

[1]The USDA / USAID Forestry Support Program and the US Forest Service's Southern Research Station are developing and testing data collection and analytical techniques for assessing the socio-economic impacts of agroforestry projects (Mercer, 1993).

In Section 2, we develop the conceptual framework for isolating and estimating the on-site soil conservation benefits of agroforestry practices. In Section 3, the evaluation framework is adapted to a case study from Eastern Visayas, Philippines, which provides the data to test this methodology. Section 4 presents and discusses the econometric results of the application. Finally, in Section 5 we briefly summarize the methodological and policy recommendations from this study.

2. Towards a value of soil conservation

Economists argue that the theoretical basis for rigorous economic analysis of agroforestry practices is woefully lacking and empirical analyses are rare (e.g. Scherr, 1992). For example, after reviewing 108 agroforestry project evaluations, Scherr and Müller (1991) conclude that only a few even attempted to assess economic impacts. At the same time, while there has been considerable economic research on the causes of change in agricultural productivity in general, conventional neoclassical economics has rarely been used to understand the role of natural resources stocks such as soil in providing flows of non-market services such as soil conservation (Pagiola, 1993). Even the few economic analyses of soil conservation have considered soil quality only in terms of erosion related problems (Lal and Stewart 1992). El-Swaify et al. (1985) review the basic economic analyses of soil conservation. McConnell (1983) and Barbier (1988) provide theoretical approaches for evaluating soil conservation benefits with an optimal control model in which soil quality is the state variable, while Bishop and Allen (1989) and Cruz et al (1988) empirically estimate the cost and benefits of soil erosion.

The paucity of economic valuations of soil conservation and agroforestry can be explained by several factors including: the spatial and temporal complexity of agroforestry systems; heterogenous farm conditions at the inter and intra household level; multiple inputs and outputs; and the existence of several non-market costs and benefits. All these factors make rigorous statistical analysis very difficult. Understanding the long run impact of a change in soil quality on agricultural productivity in particular, and societal welfare in general, requires extensive economic and agro-ecological panel data with significant length and width (time series and cross sectional variation). In a rare study, Ehui et al. (1990) evaluated alley farming systems with a farm budgeting approach with a 10-year time series data set from field trials in south-western Nigeria. However, the study did not isolate soil conservation benefits. While there are a few economic analyses of the long term potential of agroforestry (Ehui et al., 1990; Francisco and Mercer, 1995; Sullivan et al., 1992; Stocking et al., 1989), almost none of them disentangle soil conservation benefits.

Soil conservation benefits can be evaluated by the three stage analysis depicted in Figure 1.[2] Stage 1 quantifies the relationship between soil conservation, through agroforestry (*A*), and soil quality, (*S*). In Stage 2 the effects of changes in soil quality on individual household agricultural production (*Y*) are estimated. Finally, in Stage 3 these production changes production are valued at net market prices.

Stages 1 and 2 represent bio-physical relationships which are evaluated in economic terms in stage 3. This three stage analysis can be described with the following three equations:

<u>Stage 1</u>: $$\mathrm{S} \qquad S\ (z,\ \mathrm{A}) \qquad \textbf{(1)}$$

Soil quality, represented by an index (*S*), is a function of management practice (*A*), including agroforestry practices, and a vector of environmental variables (*z*) composed of geologic material, topography, climate, time and biota.

<u>Stage 2</u>: $$\mathrm{Y} \qquad Y\ (\mathrm{S},\ x) \qquad \textbf{(2)}$$

Agricultural production (*Y*) is a function of soil quality (*S*) and a vector of other human and non-human physical and financial inputs (*x*).

<u>Stage 3</u>: $$\mathrm{I} \qquad I\ (\mathrm{Y},\ \mathrm{x},\ \mathrm{P},\ \mathrm{w}) \qquad \textbf{(3)}$$

The economic value of the agricultural production (*I*) is a function of production (*Y*) , a vector of the inputs used (*x*), and a vector of output and input prices (*P* and *w* respectively). Each of the above equations is expressed in a simplified form to highlight the significance of the variables of interest, *A*, *S*, *Y* and *I*. Moreover, to the extent possible, it is important to isolate the effects of the key variables, *A*, *S*, and *Y*, in the functional forms in each of the three stages.

This three stage framework can be used to isolate and estimate the soil conservation benefits of agroforestry practices. In Stage 1, the relationship between agroforestry (A), the land use change, and soil quality (S) is estimated. This requires the formulation of an aggregate soil quality index, S, composed of several key physical, chemical and biological soil characteristics. Using these characteristics as independent variables would likely create multi-colinearity problems. Previous studies used a weighted average of water holding capacity, aeration, bulk density, pH, and electrical conductivity as a "Productivity Index" to aggregate soil quality (Larson et al., 1983; Larson and

---

[2]Three-stage analyses of this form have been proposed by Freeman (1993) for examining the relationship between the economic concept of value and the bio-physical dimensions of the natural resources or resource systems being valued. See Kramer et al, (1995) for an application of this framework for the estimation of watershed protection benefits of a forest reserve in Eastern Madagascar.

Pierce (1991). Following the Universal Soil Loss Equation which links vegetative cover and erosion control practices to the volume of soil eroded (Wischmeier and Smith, 1978), our *A* value (agroforestry practice variable) is related to the aggregate index, *S*. Partial equilibrium analysis is used to isolate the effect of *A* on *S*.

The objective in Stage 2 is to relate a change in *S* to the agricultural production profile which includes yield changes as well as allocation of labor, capital and other inputs. Although some agronomy research relates individual soil characteristics to agricultural yields, aggregate soil quality indices are rarely, if ever, used (Olson and Olson, 1986; Aune and Lal, 1995). In general, agronomic analyses of soil productivity use one of the following three basic approaches for estimating yield as a function of soil properties: (I) systematization of observed yield levels, (ii) statistical analysis of observed yield levels and (iii) bio-physical simulations (van Diepen et al., 1991). These three general approaches differ in degrees of accuracy, complexity, flexibility, and above all, data requirements. In practice, the method (or combination of methods) chosen is likely to be driven by the availability of data (Pagiola, 1993). Irrespective of the method chosen, one must identify the impact of soil quality change on productivity.

In Stage 3, the objective is to estimate the market or net economic value of the change in agricultural productivity which results from the change in soil quality, which in turn originates from the management decision to conserve the soil. Although environmental valuation is a fairly well charted field (Freeman, 1993; Pearce et al., 1994; Hufschmidt et al., 1983), three caveats are necessary. First, the value of the conservation practice should be measured net of costs. Soil conservation practices require different amounts of physical and labor inputs directly and also directly and indirectly (through its impact on *S*). This implies different costs to the farmer. Therefore, the gains in agricultural productivity need to be measured over and above (net of) these costs. Second, market prices adjust to changes in demand and supply decisions made by economic agents as they realize that the values of the conservation practice and of the soil quality are changing. Assumptions regarding the market structure should be explicitly stated. Third, soil improvement or degradation is a temporal process; that is *S* is a time dependent "stock" variable. Hence, a time series of *Y* values, the yield stream, is associated with the stream of changes in *S*. The *I* value calculated in Stage 3 is, therefore, the sum of the discounted yield stream valued net of costs.

3. Empirical Test: Contour Farming in the Eastern Visayas, Philippines

The data to test this framework were drawn from two USAID/Government of Philippines projects at two sites, Cagnocot and Visares, on the island of Leyte in the Eastern Visayas, Philippines. The projects began in the early 1980's, with financial support from USAID through 1988. The data were collected through an extensive socio-economic survey of 244 agricultural households, both adopters and non-adopters of agroforestry technology, at both sites in 1993 and 1994 (Francisco and Mercer, 1995). All known adopters who were still living at the project site at the time of the survey were included in the sample. Other sample respondents were drawn randomly from the voters' lists in the study areas.[3]

The primary agroforestry practice introduced by the USAID projects was contour hedgerows, a form of alley cropping. Alley cropping is an agroforestry practice in which food crops are planted between "alleys" or hedges of woody perennials, preferably leguminous species. The hedges may be pruned periodically during the crops' growth to provide mulch and prevent shading of the growing crops (Nair, 1993). The underlying principle is that retaining fast growing, preferably nitrogen fixing, trees and shrubs on crop producing fields, should produce soil conditions similar to those in the fallow phase of shifting cultivation. Kang et al., (1990) provide the most extensive review of alley farming.

The contour hedgerows technique is a subset of the broader category of alley farming. The identifying characteristics of contour hedgerows are: trees, shrubs, or even grasses are planted along the "contours" of the sloping upland farm plots; the periodic prunings are place at the up slope base of the hedges to trap the eroding soil; so that over time, natural terraces are formed. In the Philippines it is often referred to as SALT (sloping agricultural land technology) (Tacio, 1991). The basic benefits of alley farming are: erosion control, enhanced soil nutrient availability, weed suppression, and enhanced fuel and fodder availability. However, the hedgerows may also produce: increased demand for scarce labor and skills; loss of annual cropping area; difficulty in mechanizing agricultural operations; and excessive competition for soil nutrients, light, and water with the crops (Nair, 1993). More recently Sanchez (1995) proposes that the unsubstantiated, and sometimes sentimental, enthusiasm for alley farming and contour hedgerows in the previous decade, should be evaluated with empirical evidence and objective analysis. In accordance with this proposition, this study attempts to determine if the benefits outweigh the costs in the long run.

The contour hedgerow farming, and agricultural systems in general, of the uplands of the Eastern Visayas have been the subject of a few previous economic studies (Armenia et al., 1990; Cruz et al., 1987). The basic conclusions have been that contour hedgerows were adopted to prevent soil erosion and improve soil fertility and to some extent have met these objectives. These studies suggest that due to the additional labor requirements, the net financial returns (during the first few years after adoption) are not significantly greater. Apparently, higher education levels, larger farm size, participation in public institutions and flat (as opposed to steep) parcels rather than agroforestry adoption were the foremost explanatory variables for higher net household incomes. In these studies, however, all agro-ecological factors, including soil thickness, topography, fertility, site quality, have been addressed by a single binary variable, if at all. With greater detail on and rigorous analysis of many of these agro-ecological variables, this study aims to isolate soil conservation benefits.

The two sites, Visares and Cagnocot, are hilly and, thus, subject to significant erosion. Visares has a pronounced maximum rain period in December but no dry season, and acidic soils varying from sandy loam to clay. Cagnocot receives even rainfall throughout the year except for the

[3] Francisco and Mercer (1995) provide details on survey methodology.

dry months of February to April, and its soils are extremely clayey. Both sites have schools, health centers, flea markets and village halls, though only Visares, which is on a highway, receives irrigation water. Farming is the main source of income. Corn, rice, root-crops, and banana are the dominant crops. Ipil-ipil (*luecaena leucocephala*) and kakawate (*gliricidia sepium*) are the two primary tree species used as hedgerows. Both communities engage in fishing, carpentry and other non-farm activities, and Visares has a rudimentary rattan furniture industry, introduced by the USAID project. 244 households were surveyed to obtain: (I) household socio-economic characteristics; age, farming experience, sex, education, family size, membership in public institutions, and years of residency, (ii) farm production budgets; outputs of subsistence and commercial crops, timber, fuel, fodder, and livestock; inputs of labor, land, agricultural capital, and other material inputs, gross revenues from sale, cost of production, remittances, wage-income and other sources of income, and (iii) agro-ecological profile; slope, type of land (upland or lowland), soil attributes of thickness, fertility and texture, and water quality (Francisco and Mercer, 1995).

Applying the framework described in Section 2 to this case, requires one significant modification. The technical production relation in Stage 2, between agricultural outputs, Y, and inputs, X, and soil quality, S, is not explicitly estimated. Soil quality is assumed to effect agricultural household welfare via implicit production relations. Maler (1991) has argued that theoretically correct and empirically meaningful insights are possible without explicitly estimating the production relation. This also follows the results from duality theory, where the use of cost and profit functions assume an implicit production relation without explicitly estimation (Varian, 1992). Thus, Stage 3 directly estimates the relationship between S, and household welfare, measured in terms of net household income, I.

The production function is not explicitly modeled because of insufficient data on input allocation between various household production activities and the sheer number of different household production activities. A typical household grows more than 4 annual cash and subsistence crops, and 3 contour hedgerow perennials, keeps more than 4 livestock species, and earns income from 3 sources other than farming. The survey did not generate specific input allocation amongst these various household production processes. For example how much labor is spent tending to each of the 4 crops, 3 perennials, livestock, or on the off-farm agricultural and non-agricultural income generating activities is not known. The prodigious number, and combinations, of household products makes it difficult to elicit the nature and composition of the joint-production process. Thus, the estimation of multi-crop production functions (Shumway et al, 1984) and joint-production functions (Just et al, 1983) are beyond the scope of this analysis. Estimating agroforestry production functions is an area in need of considerable research.

There are two other conceptual clarifications for this framework. First, lack of data on annual soil quality changes has dictated the use of a lump sum, one-time (since the initiation of agroforestry practices) change in S as the crucial explanatory variable in Stage 2*. Second, because the farmers of Eastern Visayas are small relative to the market in which they sell and buy, they are assumed to be price takers. Therefore, market clearing prices are used to monetize the physical input and output variables in Stage 2*.

For Stage 1, the relationship between agroforestry, other soil management practices, and soil quality (S) is established by using the data on soil quality reported by the households that adopted A. Appendix 1 presents the construction of the indices used in the analysis. The vector of agroforestry indices, A, includes the following: (I) the agroforestry index, a_1, described by the extent of contour hedgerows installed, (ii) a binary variable for the presence or absence of other soil conservation practices, a_2, (iii) the reason for adopting contour hedgerows, a_3, (iv) the frequency of mulching, a_4. S comprises a weighted combination of the survey respondent's perception of the quantity of soil erosion and the quality of soil described by fertility and texture. Thickness, texture, and fertility are assumed to capture the effects of the crucial soil bio-physical and bio-chemical processes.

The multiple regression analysis follows Aune and Lal (1995) and Olson and Olson (1986). The regression of S, is described by the following equation (4), where the ÷$_i$'s are the regressors listed in Table 1:

$$\mathrm{Ln}(S) \qquad \sum_{0}^{8} \text{á}_i \; \mathrm{Ln}(\div_i \qquad k) \tag{4}$$

The double logarithmic specification for this regression is a variation of the conventional Cobb-Douglas form. The constant k relaxes the rigid requirement that the independent variables are "essential" (Heady and Dillon, 1961). For every regressor, $k > 0$ implies that if the regressor is equal to zero, then the value of the dependent variable is not zero, but is instead determined by the other regressors. In this analysis $k = 1$.

Equation 5 describes the multiple regression for Stage 2*. I is regressed on the ø$_i$ regressors that include labor, capital and other inputs, household specific attributes, and the S, a_1, and a_2 variables.

$$\mathrm{Ln}(I) \qquad \sum_{0}^{13} \text{â}_i \; \mathrm{Ln}(\text{ø}_i \qquad j) \tag{5}$$

This analysis is similar to the one conducted by Armenia et al. (1990). Again, the use of a generalized form of the Cobb-Douglas function, with $j = 1$, relaxes the rigid requirement that all regressors be essential[4]. The calculation of the I value used in the regression is explained in Appendix 1. The regression co-efficient on the S variable measures the elasticity of net household income with respect to soil quality.

---

[4]Given, that on the average farm income comprises 30 percent of net household income for the respondents and the fact that most of the regressors used in this analysis are specific to farming activities, a model that allows for non-essential explanatory variables is particularly relevant for this study.

In equation 6, The marginal value of soil conservation (from contour hedgerows) is integrated over the range of a_1 to obtain a total contribution to annual per household net income, V_i.

$$V_i \quad \int_0^{a_{1i}} \tilde{o}_i \; da_1 \qquad \int_0^{a_{1i}} \frac{I}{S} \; \frac{S}{a_{1i}} \; da_1 \tag{6}$$

$$i \quad \text{set of households}$$

This marginal soil conservation value per unit of contour hedgerow activity, õ, is the indirect effect of a_1 on I through a_1's effect on S which in turn determines I. The degree of contour hedgerow adopted by each household sets the range for a_3.

Estimating the net present value of "agroforestry induced" soil conservation, W, requires both spatial and temporal aggregation. Household specific V_i are summed over the total number of households practicing agroforestry. Issues considered in temporal aggregation include: the length, in terms of number of years, of the project, T; the rate at which contour farming is increasing, r_A; the rate at which the average change in S is improving for the technology adopters, r_S ; and the social rate of discount r_T. The following two equations (7 and 8) modify the above set to incorporate the temporal and spatial rates of change necessary for the estimation of W.

$$W \quad \sum_t^T \left[\frac{(1 \quad r_A) \quad (\sum_i^N V_i)}{(1 \quad r_T)}\right]^t \tag{7}$$

$$V_i \quad \int_0^{a_{1i}} \tilde{o}_i \; da \qquad \int_0^{a_{1i}} (1 \quad r_s) \; \frac{I}{S} \; \frac{S}{a_{1i}} \; da \tag{8}$$

4. Results and Discussion

The regression results for Stage 1 are presented in Table 1. The double log specification successfully explains 53% of the variation (Adjusted R-square). Although the regression co-efficients do not measure the slope, the signs suggest the direction of the relationships between the regressors and the dependent variable. The contour hedgerow index, the dummy for other soil management practices and for site, and the variable that indicates that soil conservation was the reason for adopting the contour hedgerow technology, are all significant at the 5% level. The sign of the regression co-efficient on the contour hedgerow variable is positive indicating a proportional relationship between agroforestry and soil quality. This provides empirical verification for the claim that agroforestry enhances soil quality. The variable measuring frequency of mulching is significant at the 10% level. The negative sign suggests that erosion control rather than fertility enhancement is the main benefit of contour hedgerowing in these sites.

The Stage 2* regression results are presented in Table 2. Labor inputs, material capital inputs, farm size, average education of household adults, tenure status and public institutional affiliation were significant variables. Interestingly, education, institutional affiliation, labor and tenure were also statistically significant regressors in the previous study that tried to explain net household income for the farmers of Eastern Visayas (Armenia, 1990). The regression co-efficients for most of the variables show the intuitively expected sign.

Most crucially, soil quality is positively correlated with net household income (*I*). Again this validates the conventional wisdom that protection of natural capital, like soil resources, pays dividends in the form of higher annual income flows. The statistical insignificance of this variable may be attributed to two reasons. First, improved soil may require a lengthy gestation period before it significantly affects net household income. Second, soil quality primarily affects income from food or tree crops, which comprise only about 30% of the estimated *I*. While contour hedgerow activity is negatively correlated with *I*, the variable for other soil conservation practices is positive. The reason for this may be the high opportunity cost of contour hedgerows in terms of scarce farm land, labor, and agricultural capital. Moreover, as in the case of soil quality, the length of time necessary for the benefits to outweigh the costs may be significant.

The negative sign on the co-efficient of labor variable suggests that the opportunity cost of labor in non-cash crop activity is high. By using family labor on farm for agroforestry activities, households may be sacrificing more lucrative alternative sources of income off-farm. As expected, higher inputs of seeds, fertilizers, and other material capital increases *I*. Higher education, ownership of farm (tenure status), and public institutional affiliations also positively affect *I*. Even though their co-efficients were insignificant the signs of the co-efficients suggests that households that were from Visares, that had a greater number of household adults, that had a higher average age for adults, and that occupied their farms for longer are likely to have higher net household incomes.

Table 3 reports the estimated average per household agroforestry induced soil conservation value, *V*, which is calculated with equation 6. It is important to note that these values are estimated for an "average" household.[5] When estimating the net present value of agroforestry related soil conservation using equations 7 and 8, the individual household specific V_i are aggregated over the set of all households. The aggregation also uses $T = 20$ years, $r_T = 0.1$, $r_A = 1.05^{-t}$, $r_S = 0.09^{-t}$; where t is the number of years since 1983, the year in which USAID initiated the contour hedgerow projects in the Eastern Visayas. The r_A and r_S are generated from a time trend regression analysis of the cumulative number of contour hedgerow farmers and the reported S values respectively. A 10%

[5]This "average" or representative household is described by average values, calculated across the set of 244 households, for each of the variables used in the two stages.

discount rate and 20 years project length are fairly typical for evaluations of development projects funded by USAID and other international development agencies. However, their use is arbitrary because arguably the soil conservation will be realized over an infinite time horizon, and every farmer of Eastern Visayas does not discount the future at a 10% annual rate. Both these values are used to explain the aggregation methodology, rather than to inform policy on regional agroforestry projects in general.

6. Conclusion

The objective of this study was to design and test a methodology for valuing agroforestry soil conservation benefits. The conclusions fall in two categories: methodological and policy implications.

The necessary modifications of the theoretical framework for application to the Philippines case makes apparent the complication of modeling agroforestry systems. The sheer multiplicity of products necessitated the aggregation of the dependent variables into the solitary monetized form of net household income. The theoretical allowance for intra-household substitution is perhaps the greatest advantage of this modification. The alternatives are either to model a simpler system with four to five products, or to collect product-specific data on household input allocations. Both of these would use all three stages of the framework. Two additional methodological observations are important. First, even though the survey was designed to elicit information on the chronology of adoption, there was insufficient time series "length" to detect trends or to determine if the survey year was typical. Future evaluations are advised to either conduct repeat surveys with a time lag, or to maintain regular annual records for a sub-sample of the surveyed households. Second, the agro-ecological variables are self-reported. "Ground truthing" by engaging the soil conservation service to obtain precise scientific measurements for a sub-sample of the households may have improved the reliability of the results.

The positive values for I in Table 3, soil quality in Table 2, and for contour hedgerow activity in Table 1, all indicate that agroforestry-related soil conservation does benefit the farmer. This in itself, however, is not a sufficient incentive for the farmer to invest in agroforestry. As the negative co-efficient on the a_1 variable in Stage 2* indicates, agroforestry imposes direct opportunity costs on the agricultural households. Farmers will voluntarily participate in agroforestry practices only if the net benefits are positive. The net benefit of agroforestry practices can be calculated by incorporating the direct effects, (I / a_1), into equation 6. For the "average" household the total net benefit (a sum of the direct and indirect effects) is -970 pesos. The annual value for the 244 households surveyed, is -162,000 pesos. Thus, the opportunity costs of agroforestry clearly outweigh the specific soil conservation benefits. Farmers are unlikely to practice agroforestry without some form of financial, material and technical assistance.

Two caveats to this conclusion are necessary. First, the specific soil conservation benefits calculated here are edaphic. These estimates do not account for several significant off-site and on-site benefits that are external to the individual households. Therefore even if the net contribution of agroforestry to individual household income is negative, net benefits to society, including the external benefits and project related costs, are likely to be positive. Thus, there may be good reason for society to implement an incentive system, through subsidies or extension services, for the farmers to practice agroforestry that would conserve the soil and enhance overall societal welfare. Second, all "long run" soil conservation benefits, and particularly improvements in the agro-ecological profile, may not have been realized in the short ten year period since the initiation of the agroforestry project. Both of these caveats imply that the analysis is conservative in spirit and has generated lower bounds for agroforestry related soil conservation benefits.

In answer to Sanchez's (1995) call for more objective analysis of agroforestry systems, this study has attempted to satisfy two goals: to provide a framework for estimating soil conservation benefits in general and to test the approach with empirical evidence from contour hedgerow practices. This exploratory attempt can serve as the basis for both preliminary valuation of soil conservation and agroforestry projects and further improvements of the analytical techniques in and outside the field of agroforestry.

Literature Cited

Armenia , P. T., A. C. Y. Sandoval, and S. E. Abit, 1990. Technology Assessment for Hilly Land Farming Systems in Eastern Visayas. In A. R. Librero (ed), Technology Assessment for Agriculture in the Philippines. Philippine Council for Agriculture, Forestry and Natural Resources Research and Development and the International Development Research Center.

Aune, J. B., and R. Lal, 1995. The Tropical Soil Productivity Calculator: A Model for Assessing Effects of Soil Management on Productivity. In R. Lal and B. A. Stewart (eds), Soil Management: Experimental Basis for Sustainability and Environmental Quality. Advances in Soil Sciences. CRC, Florida.

Barbier, E. B., 1988. The Economics of Farm-Level Adoption of Soil Conservation Measures in the Uplands of Java. Environment Department Working Paper No. 11, The World Bank, Washington D.C.

Bishop, J., and J. Allen, 1989. The On-Site Costs of Soil Erosion in Mali. Environment Department Working Paper No. 21, The World Bank, Washington D.C.

Clark, E., H. Haverkamp, and W. Chapman. 1985. Eroding Soils: The Off Farm Impacts. Conservation Foundation, Washington, D.C.

Crosson, P., with A. Stout. 1983. Productivity effects of cropland erosion in the United States. Resources for the Future, Washington, D.C.

Cruz, Ma C. J., with A. J. Alcantara, W. D. Cruz, F. P. Lansigan, R. B. Mendoza, and P. E. Sajise, 1987. Philippine Upland Production Systems: An Integrative Analysis of Three Sites. University of Philippines at Los Banos Institute of Environmental Science and Management.

Cruz, W., H. Francisco, and Z. Conway, 1988. The On-Site and Downstream Costs of Soil Erosion in the Magat and Pantabangan Watersheds. *Journal of Philippine Development* 15 (1).

Ehui, S. K., B. T. Kang, and D. S. C. Spencer, 1990. Economic Analysis of Soil Erosion Effects in Alley Cropping, No-till and Bush Fallow Systems in South Western Nigeria. *Agricultural Systems* 34: 349 - 368.

El-Swaify, S., W. Moldenhauer, and A. Lo (ed). 1983. Soil Erosion and Conservation. Iowa.

Francisco, H. A., and D. E. Mercer, 1995. Economic Impact Assessment of Agroforestry Technologies in two USAID Projects in Leyte, Philippines. Southeastern Center for Forest Economics, Research Triangle Park, NC.

Freeman, A. 1993. The Measurement of Environmental and Resource Values: Theory and Methods. Resources For the Future, Washington, D.C.

Gregersen, H., K. Brooks, J. Dixon and L. Hamilton. 1987. Guidelines for Economic Appraisal of Watershed Management Projects. FAO Conservation Guide No. 16. FAO, Rome.

Heady, E. O., and J. L. Dillon, 1961. Agricultural Production Functions. Iowa State University Press, Iowa.

Hufschmidt, M. M., D. E. James, A. D. Meister, B. T. Bower, and J. A. Dixon. Environment, Natural Systems, and Development: An Economic Valuation Guide. Johns Hopkins University Press, Baltimore.

Just, R. E., D. Zilberman, and E. Hockman, 1983. Estimation of multi-crop production functions. *American Journal of Agricultural Economics* 65: 770 - 780.

Kang, B. T., L. Reynolds, and A. N. Atta-Krah, 1990. Alley Farming. *Advances in Agronomy* 43: 315 - 359.

Kramer, R. A., D. D. Richter, S. Pattanayak, and N. Sharma, 1995. Economic and Ecological Evaluation of Watershed Protection in Eastern Madagascar. (*forthcoming*) *Journal of Environmental Management*.

Lal, R., and B. Stewart. 1992. Need for Land Restoration. In: R. Lal and B. A. Stewart (eds), Advances in Soil Sciences Volume 17. Springer-Verlag, New York.

Larson, W., F. Pierce and R. Dowdy. 1983. Loss in long term productivity from soil erosion in the United States. In: S.A. El-Swaify, W.C. Moldenhauer, and A. Lo (eds), Soil Erosion and Conservation., Iowa.

Larson, W. E., and F. J. Pierce, 1991. Conservation and Enhancement of Soil Quality. In: Evaluation for Sustainable Land Management in the Developing World. Volume 2: Technical Papers. International Board for Soil Research and Management. Bangkok, Thailand.

Lundgren, B. O., and J. B. Raintree, 1982. Sustained Agroforestry. In B. Nestel (ed.) Agricultural Research for Development: Potential and Challenges in Asia. ISNAR, The Hague, Netherlands. pgs 37 - 49.

Lutz, E., S. Pagiola, and C. Reiche. 1993. Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean. World Bank Environment Paper No. 8. Washington, D.C.

Magrath, W., and P. Arens. 1989. The Cost of Soil Erosion on Java: A Natural Resource Accounting Approach. Environment Division Working Paper No. 18. World Bank. Washington, D.C.

Maler, K-G, 1991. The Production Function Approach in Developing Countries. In J. Vincent, E. W. Crawford, and J. P. Hoehn (eds), Valuing Environmental Benefits in Developing Economies. Proceedings of a Seminar Series, sponsored by the Michigan State University Graduate Specialization in Resource Economics. East Lansing, Michigan.

McConnell, K. E., 1983. An Economic Model of Soil Conservation. American Journal of Agricultural Economics 65 (1): 83 - 89.

Mercer, D. E., 1993. A Framework for Analyzing the Socio-Economic Impacts of Agroforestry Projects. FPEI Working Paper No. 52. Southeastern Center for Forest Economics, Research Triangle Park, NC.

Nair, P. K. R., 1993. An Introduction to Agroforestry. Kluwer, Boston.

Olson, K. and G. Olson. 1986. Useful multiple regression analysis to estimate average corn yields using selected soil and climatic data. *Agricultural Systems* 20: 105 - 120.

Pagiola, S. 1993. Cost Benefit Analysis of Soil Conservation. In: Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean. World Bank Environment Paper No. 8. World Bank, Washington, D.C.

Pearce, D., D. Whittington, and S. Georgiou, 1994. Economic Values and the Environment in the Developing World. A report to UNEP. Unpublished Manuscript.

Repetto, R., and W. Cruz. 1991. Accounts Overdue: Natural Resource Depreciation in Costa Rica. World Resources Institute. Washington D.C.

Sanchez, P. A., 1987. Soil productivity and sustainability in agroforestry systems. In H. A. Seppler and P. K. R. Nair (eds), Agroforestry: A Decade of Development. International Council for Research in Agroforestry, Nairobi, Kenya. pp 205 - 223.

Sanchez, P. A. 1995. Science in Agroforestry. *Agroforestry Systems* 30 (1 & 2): 5 - 55.

Scherr, S. J., 1992. Not out of the Woods Yet: Challenges for Economics Research on Agroforestry. *American Journal of Agricultural Economics* 74 (3): 802 - 808.

Scherr, S. J. and E. U. Müller, 1991. Technology impact evaluation in agroforestry projects. *Agroforestry Systems* 13: 235 - 258.

Shumway, C. R., R. D. Pope, and E. K. Nash, 1984. Allocatable Fixed Inputs and Jointness in Agricultural Production: Implications for Economic Modeling. *American Journal of Agricultural Economics* 66: 72 - 78.

Stocking, M., J. Bojo, and N. Abel, 1989. Financial and Economic Analysis of Agroforestry: key issues. Workshop on Agroforestry for Sustainable Development - Economic Implications. Commonwealth Science Council, Mbabane, Switzerland.

Sullivan, G. M., S. M. Huke and J. M. Fox (eds), 1992. Financial and Economic Analyses of Agroforestry Systems. Proceedings of a workshop held in Hawaii, U.S.A. Paia, Hawaii, Nitrogen Fixing Tree Association.

Tacio, H. D., 1991. The SALT System: Agroforestry for Sloping Lands. *Agroforestry Today* 3(1):-12-13.

van Diepen, C., H. van Keulen, J. Wolf, and J. Berkhout. 1991. Land Evaluation: From Intuition to Quantification. In: B.A. Stewart (ed), Advances in Soil Science. Vol 15. Springer-Verlag, New York.

Varian, H. 1992. Micreconomic Analysis. W.W. Norton and Company, New York.

Walker, D. J., and D. L. Young, 1986. The Effect of Technical Progress on Erosion Damage and Economic Incentives for Soil Conservation. *Land Economics* 62 (1) : 83 - 93.

Wischmeier, W., and D. Smith. 1978. Predicting rainfall erosion losses. Agriculture Handbook No. 537. USDA, Washington, D.C.

Young, A., 1989. Agroforestry for Soil Conservation. CAB International, Oxford, U.K.

Appendix 1: Indices Used

1.1 Agroforestry and Soil Management Indices (A: a_1, a_2, a_3, a_4):

$$a_1 \quad ((0.25 \ a_{11}) \quad (0.75 \ a_{12})) \ t_{a1}$$

$$a_3 \quad \sum_{n}^{3} \mu_n \quad a_{n3}$$

$$\mu \quad (0.5, \ 0.3 \ ,0.2) \tag{9}$$

$$a_4 \quad \frac{a_4}{Max \ (a_4)}$$

a_1: contour hedgerow activity index
a_{11}: extent of farmland under contour hedgerows now
a_{12}: extent of farmland under contour hedgerows in the year of adoption
a_2: dummy for other soil conservation practices
a_3: whether soil quality was a concern in adopting contour hedgerows
a_4: frequency of pruning contour hedgerows for mulch purposes
t_{a1}: number of years since contour hedgerows were established

1.2 Soil Quality Index (S):

$$\mathbf{S} \quad (\sum_{\mathrm{i}}^{3} \ \text{á}_{\mathrm{i}}\text{ÄS}_{\mathrm{i}})$$

$$\text{á}_i \quad (0.6, \ 0.3, \ 0.1) \tag{10}$$

ÄS$_i$: reported change in top soil attributes
s_1: increase in thickness of top soil
s_2: increase in fertility of top soil
s_3: increase in texture (fine to coarse) of top soil

1.3 Net Farm Income (I):

$$\mathbf{I} \qquad \sum_{1}^{z} I_z \quad w_1x_1 \quad w_2x_2 \tag{11}$$

I_1: Cash crops
I_2: Perennial crops
I_3: Livestock
I_4: Hedgerow products
I_5: Wage Income
I_6: Non-farm Income
I_7: Remittances
x_1: Labor inputs
x_2: Physical capital inputs
w_1: per unit labor cost
w_2: per unit physical capital cost

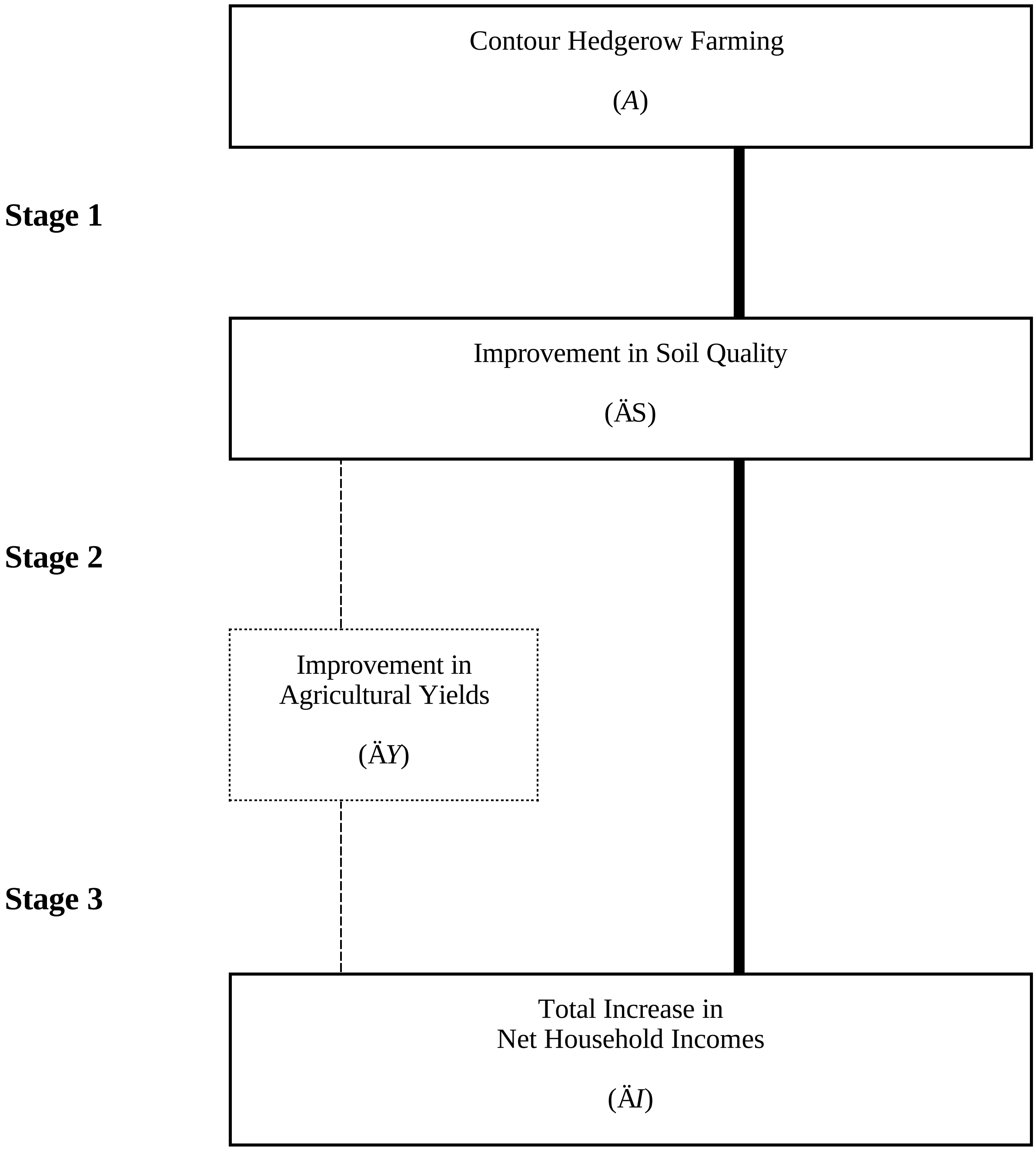

Figure 1. Three stage framework for Valuation of Soil Conservation Benefits of Agroforestry

Table 1. Stage 1 Regression Results: Determinants of Natural Log of Soil Quality.

Variable: Logarithm (÷$_i$)	Coefficient	p-Value (t statistic)
intercept	-0.050	0.058 (-1.454)
land type: upland or lowland	0.082	0.144 (1.468)
slope	0.012	0.734 (0.341)
dummy for site **	0.038	0.040 (2.066)
years of use	0.004	0.546 (0.604)
contour hedgerow activity index **	0.070	0.000 (4.873)
dummy for other soil conservation practice **	0.137	0.000 (4.564)
frequency of application of mulch *	-0.028	0.082 (-1.746)
soil conservation related reasons ** for adopting contour hedgerows	0.129	0.000 (4.151)
Number of Observations	244	**: significant at á = 5%
F-statistic	35.397	*: significant at á = 10%
Adjusted R square	0.53	

Table 2. Regression Results for Stage 2: Determinants of Natural Log of Net Household Income).

Variable: Logarithm ($ø_i$)	co-efficient	p-value & (t-statistic)
intercept **	6.521	0.000 (5.912)
labor **	-0.298	0.000 (-3.715)
material capital **	0.186	0.001 (3.226)
farm size **	0.304	0.013 (2.496)
average age	0.368	0.194 (1.302)
institutional affiliations **	0.905	0.028 (2.207)
average education **	0.763	0.000 (3.705)
tenure status *	0.443	0.109 (1.610)
years of use	0.016	0.863 (0.172)
dummy for site	0.087	0.701 (0.385)
number of adults	0.278	0.207 (1.265)
contour hedgerow activity index	-0.214	0.144 (-1.466)
dummy for other soil conservation practices	0.485	0.163 (1.400)
soil quality index	0.345	0.631 (0.481)
Number of Observations	244	**: significant at á = 5%
Adjusted R Square	0.31	*: significant at á = 10%
F-statistic	9.197	

Table 3. Value of Agroforestry induced Soil Conservation*

Soil Conservation Value of Agroforestry for average household (V)	Net Present Value of Soil Conservation Benefits from agroforestry in the Eastern Visayas (W)
114 Pesos	232,800 Pesos

* 1 Peso = US$.04